Incorporating the Effects of Smart Growth and Transit Oriented Development in San Francisco Bay Area Travel Demand Models: Current and Future Strategies

By:
Charles L. Purvis, AICP
Planning Section
Metropolitan Transportation Commission
101 Eighth Street
Oakland, California 94607

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EXECUTIVE SUMMARY

The purpose of this paper is to explore issues and opportunities for improving the performance of existing and future sets of MTC travel demand models, with respect to the Bay Area's Smart Growth Regional Vision. This paper outlines short-term strategies that are recommended for incorporation into MTC's model system, before work commences on the 2004 update of the Regional Transportation Plan. Longer-term strategies, including redevelopment of MTC demand models, are also introduced in this paper.

Some of the premises, or hypotheses related to Smart Growth include:

1. Mixed use, compact growth will tend to decrease average trip length for all trip purposes.
2. Decreases in average trip lengths will tend to increase non-motorized travel shares.
3. Mixed use, compact growth will have the effect of reducing walk-to-transit access times, and will tend to increase transit shares.
4. Compact growth will tend to have higher levels of multi-story, multi-family housing units. This, in turn, will yield lower levels of vehicle availability, which in turn, leads to lower trip generation and higher non-auto travel shares.

Two basic groups of strategies have been identified to test and evaluate these Smart Growth Premises. The first group relates to adjustments to the input socio-economic databases, produced by ABAG and split / adjusted by MTC staff. The second group of strategies relates to adjustments to the highway, transit and non-motorized transportation networks used to represent zone-to-zone travel times, distances and costs.

The following is a summary of the seven detailed strategies that are recommended for incorporation into MTC's modeling methodology within the next six months.

SMART GROWTH ADJUSTMENTS TO MASTER ZONAL DATABASES

1. Update zonal allocation procedures ("zap") to incorporate new Census 2000 journey-to-work data, expected November-December 2003.
2. Update the future year zonal allocation procedures in MTC's "split tract" zones to incorporate Smart Growth allocation of jobs and housing.
3. Apply improved procedures to predict the proportion of multi-family dwelling units for all travel analysis zones.
4. Review and update single-family and multi-family household data in Smart Growth neighborhoods.

SMART GROWTH ADJUSTMENTS TO TRAVEL MODEL NETWORKS

1. Adjust intra-zonal travel times for auto, transit and non-motorized networks to reflect higher density, compact development within Smart Growth neighborhoods.

2. Adjust auto network “terminal times and distances” to reflect higher density, compact development.
3. Adjust transit network walk access connector links to reflect higher density, compact development.

Long-term, post-RTP-forecasting strategies will focus on the redevelopment of MTC travel demand models using new sets of data from the year 2000 Bay Area Travel Survey (BATS2000) and Census 2000 data. The BATS2000 data is a rich dataset providing two-day activity diary data for over 15,000 Bay Area households. It will serve as the major data source for estimating new sets of trip-based, activity-based, or tour-based travel model systems.

One basic premise for the MTC long-term model development strategy is that the model estimation, calibration and validation efforts will be an in-house activity. This has been a basic MTC tenet since the late 1970s. Developing models in-house has two major advantages: 1) major cost savings in consultant fees; and 2) improving staff competency, satisfaction and achievement. Still, however, significant consultant contracts will be required to provide MTC staff with the necessary training, tutoring, and technical advice, and other consultant activities to be determined (model system specification, computer programming, review of literature, peer guidance).

We propose to assemble a peer group review panel before we proceed on any consultant contract to assist in preparing MTC’s long-term model development strategy. MTC can probably rely on some financial assistance from the US Department of Transportation to support this panel, from either the federal Travel Model Improvement Program (TMIP) or direct assistance from the Federal Transit Administration (FTA). The most opportune time for this peer group review panel is summer or fall 2004. The peer panel could provide brainstorming advice on a number of topics, including but not limited to:

1. Training, tutoring and technical oversight from consultants;
2. Representing Smart Growth strategies in networks, zone, and demand models;
3. Options for trip chaining, tours, and trip linking/chaining technical procedures;
4. Best practices in destination choice modeling;
5. Best practices in local/regional agency model coordination;
6. Calibration and validation principles and aspirations;
7. Long term data collection strategies (e.g., BATS2010)

I. INTRODUCTION

The purpose of this paper is to explore issues and opportunities for improving the performance of existing and future sets of MTC travel demand models, with respect to the Bay Area's Smart Growth Regional Vision. The first major step in this effort is to base new sets of MTC travel demand forecasts on the Association of Bay Area Governments' (ABAG) "Projections 2003." These new "smart growth" socio-economic forecasts were produced by ABAG at the census tract level, and are available at five-year increments between 2000 and 2030.

> *"Smart growth can best be described as development that revitalizes central cities and older suburbs, supports and enhances public transit, promotes walking and bicycling opportunities, and preserves open spaces and agricultural lands. Smart growth is not 'no growth;' rather, it seeks to revitalize the already built environment and, to the extent necessary, foster efficient development at the edges of the region, in the process creating more livable communities." [Projections 2003, p. 2]*

The current set of MTC travel demand models were developed (statistically estimated) in the mid-1990s using data from the 1990 MTC household travel survey and the 1990 Decennial Census. These models were originally calibrated (adjusted) and validated (compared to observed data) for a 1990 base year. In recent years, these models were validated to a 1998 base year.

Future MTC travel demand model systems will be based on data from the year 2000 Bay Area Travel Survey (BATS2000) and Census 2000. BATS2000 collected detailed activity and travel data from over 15,000 Bay Area households throughout year 2000.

The current generation of MTC travel demand models are a comprehensive set of "trip-based" travel demand models, including the full range of travel purposes and modes. Older generations (pre-1997) of MTC models excluded non-motorized travel (bicycle, walk); the current generation includes bicycle and walk as distinct travel modes. Older generations of MTC models did not include school travel; the current generation includes separate models for grade school, high school, and college travel. Older MTC models did not have any way to evaluate "peak spreading." The new MTC model system includes a "time-of-day" choice model to predict whether or not a work trip starts in the peak period. Older MTC models did not have an explicit "truck trip" model; the new generation includes "truck trip" models borrowed from Alameda County and the USDOT.

Current plans are to calibrate and validate the existing model set to a 2000 base year, using available decennial census data and new sets of highway, transit and non-motorized networks, at MTC's new 1,454 travel analysis zone system. (MTC's 1,099 zone system will be maintained in the foreseeable future to assist county congestion management agencies in their modeling efforts.)

MTC "short-term" strategies will focus on adjustments to networks and other assumptions within the next six months, to be incorporated into new forecasts for the next update of the Regional Transportation Plan ("Transportation 2030.") It is very important that these strategies be evaluated in conjunction with current MTC efforts to re-validate the model system to the year 2000.

MTC "long-term" strategies will begin discussion on adjustments and overhauls to networks, travel behavior models and other assumptions, after work is completed on the RTP update, and beginning about late 2004. A comprehensive "model re-design" project has not started, and may commence in late 2004 depending on budget and efforts to complete work on the 2005 RTP.

MTC will also be using new data from the year 2000 Bay Area Travel Survey (BATS2000), a two-diary activity diary of over 15,000 Bay Area households. This database will serve as the centerpiece for model development activities in the Bay Area for the next several years.

Estimation, Calibration, Validation: What Do They Mean?

Estimation is the empirical, statistical estimation of travel demand model coefficients using statistical software such as ALOGIT and SAS.

Calibration is the adjustment of model constants, gravity model "friction factors," socio-economic adjustment factors, in order to produce a better model validation.

Validation is the process of comparing model-predicted choices to observed choices, including auto ownership levels, trip frequency levels, trip distribution patterns, mode choice patterns, and observed traffic and transit data.

II. REVIEW OF EXISTING TRAVEL DEMAND FORECASTS

The purpose of this section is to review existing travel demand forecasts prepared using ABAG's Projections 2000 and Projections 2003. Regional mode choice forecasts for work and total trips are provided in Table A.

The year 2000 forecasts were prepared in the fall of 2002 and are based on ABAG's Projections 2002. They are the most current set of year 2000 travel forecasts prepared by MTC.

The "RTP2001" forecasts for the year 2025 are based on ABAG's Projections 2000 and the 2001 RTP "project alternative" highway and transit networks.

The "PET2030" forecasts, also for the year 2025, are based on the newly produced ABAG's Projections 2003 socio-economic forecasts, and the same set of highway and transit networks used for the RTP2001 travel forecasts. The term "PET2030" is shorthand for "Performance Evaluation for Transportation 2030," a current MTC program to analyze project-level performance.

The *only* difference between the RTP2001-2025 and the PET2030-2025 forecasts are the input socio-economic forecasts (Projections 2000 versus Projections 2003). All of the other assumptions (horizon year, pricing, networks, travel behavior) are identical. This is then an excellent opportunity to examine the travel behavior impacts of shifting between traditional land use forecasts (Projections 2000, Projections 2002) and "smart growth" land use forecasts (Projections 2003).

It is important to note that the next set of forecasts will be based on the new MTC 1454-zone system, demand models re-validated to year 2000 data, Projections 2003 data, and "smart growth" adjustments that are specified in this report. Other assumptions such as future year gas prices, parking charges and transit fares will also need to be re-visited before the next set of travel forecasts are prepared.

Table A
Compare Regional Mode Choice Forecasts

Work Trips

	2000	RTP2001 (Proj2000) 2025	PET2030 (Proj2003) 2025	2000	RTP2001 (Proj2000) 2025	PET2030 (Proj2003) 2025
Drive Alone	3,882,300	5,088,900	5,085,800	71.7%	71.9%	68.4%
Carpool 2	584,000	740,300	857,700	10.8%	10.5%	11.5%
Carpool 3+	170,500	257,700	259,100	3.1%	3.6%	3.5%
Transit	551,700	747,400	912,300	10.2%	10.6%	12.3%
Bicycle	56,000	64,200	88,400	1.0%	0.9%	1.2%
Walk	171,900	179,200	234,400	3.2%	2.5%	3.2%
Total	5,416,400	7,077,700	7,437,600	100.0%	100.0%	100.0%

Total Trips (Work + Non-Work)

	2000	RTP2001 (Proj2000) 2025	PET2030 (Proj2003) 2025	2000	RTP2001 (Proj2000) 2025	PET2030 (Proj2003) 2025
Vehicle Driver	12,940,600	16,251,600	16,478,500	61.2%	62.0%	60.7%
Driver + Passenger	17,218,800	21,537,000	21,844,600	81.5%	82.1%	80.4%
Transit	1,314,800	1,647,200	2,030,000	6.2%	6.3%	7.5%
Bicycle	303,700	342,400	374,000	1.4%	1.3%	1.4%
Walk	2,298,800	2,700,300	2,906,900	10.9%	10.3%	10.7%
Total	21,136,100	26,226,900	27,155,600	100.0%	100.0%	100.0%

The most striking difference between the two 2025 forecasts is the increase in regional transit trips using the "smart growth" land use forecasts: 1.6 million transit trips in the old Projections 2000-based forecast and 2.0 million transit trips in the new, Projections 2003-

based forecast, an increase of 23.2 percent. Overall trip-making increases, as well, due to the increased housing production assumed in the smart growth land use forecast. Overall trips increase 3.5 percent from 26.2 million person trips to 27.2 million person trips.

Bicycle and walk trips and mode shares show a modest increase between the two 2025 scenarios. Vehicle driver trips and auto person (driver-plus-passenger) show modest increase in numbers, but decreasing modal shares.

Again, the travel forecasts summarized in Table "A" do not incorporate any of the "smart growth" adjustments discussed in this report.

As an extra piece of information, the following Table "B" compares commute mode shares from Census 2000 to the most recent MTC year 2000 forecast. This is the sort of information that will be used in the next several months to re-validate the MTC models to the best, most recent data. This particular table shows very encouraging results: the largest problem is a 0.7 percent over-estimate for two-person carpools (10.8% model-predicted versus 10.1% Census 2000); and the least significant problem is a 0.1 percent under-estimate of regional work trip transit share (10.2% model-predicted versus 10.3% Census 2000). Slight under-predictions in work trip bicycle and walk shares will also have to be corrected for in the next validation cycle. Note that the Census 2000 modal share data excludes work-at-home commuters. Note also that Census-based "commuters" measures the typical home-to-work trip, only, whereas MTC's work trips include both home-to-work and work-to-home trips.

Table B
Compare MTC Work Trip Forecast, Year 2000, to Census 2000 Commuters

	Census 2000		MTC Forecast, 2000	
Mode	Commuters	Share	Work Trips	Share
Drive Alone	2,212,567	71.5%	3,882,300	71.7%
Carpool 2	312,749	10.1%	584,000	10.8%
Carpool 3+	105,915	3.4%	170,500	3.1%
Transit	319,535	10.3%	551,700	10.2%
Bicycle	35,752	1.2%	56,000	1.0%
Walk	106,275	3.4%	171,900	3.2%
Total	3,092,793	100.0%	5,416,400	100.0%

Other important Census 2000 data that will be used in the upcoming validation cycle are the county-to-county commuters, by means of transportation, based on the 5-percent Public Use Microdata Sample (PUMS); and the workers in household / vehicles in household choice model, also using PUMS data.

Detailed, zone-to-zone commute flow data is not expected until February or March 2004, which is a significant problem in that we want to finish our re-validation efforts by April 2004, in time for preparing forecasts for the RTP update.

The next sections of this report will discuss the short term and long term strategies to incorporate smart growth principles in MTC's travel demand forecasts. In particular, the next section examines adjustments to the master zonal socio-economic databases that provide the basic inputs to our travel projections.

III. SMART GROWTH ADJUSTMENTS TO MASTER ZONAL DATABASES

Four short-term strategies are summarized in this section:

1. Update zonal allocation procedures ("zap") to incorporate new Census 2000 journey-to-work data, expected November-December 2003.
2. Update the future year zonal allocation procedures in MTC's "split tract" zones to incorporate Smart Growth allocation of jobs and housing.
3. Apply improved procedures to predict the proportion of multi-family dwelling units for all travel analysis zones.
4. Review and update single-family and multi-family household data in Smart Growth neighborhoods.

Socio-economic / land use projections are prepared by ABAG staff at the jurisdictional level (city, city sphere of influence, and "other sub-regional area".) The ABAG board adopts the jurisdictional level projections, after which ABAG staff proceeds on the labor-intensive process of sub-allocating the city and city sphere-of-influence data down to the census tract level. Recent ABAG projections series (Projections 2002, Projections 2003) are allocated to the 1,405 census tracts in Census 2000. Previous ABAG projections series used the 1,382 census tracts from the 1990 Census.

MTC's new set of 1454-travel analysis zones nest entirely within Census 2000 census tracts. There is a one-to-one equivalency between 1375 census tracts and 1375 MTC travel analysis zones. There are 30 census tracts in the Bay Area that are carved into 79 MTC travel analysis zones (1375 + 79 = 1454). The process to carve the projections data from the 30 census tracts to the 79 zones is affectionately known as a "zonal allocation procedure" or "zap" or "zapping" process.

MTC staff uses this "zapping" procedure to create a 1454-zone master zonal database from the 1405-tract database provided by ABAG. Essentially this is a mechanical process for determining what *proportion* of the census tract forecast is allocated to which travel analysis zone.

The "zap" proportions are typically based on historic census data. The proportions for zapping households, workers, and population are based on Census 2000 data. The proportions for zapping employment data is (still) based on 1990 Census data. Data from "Part 2" of the Census Transportation Planning Package (CTPP) will provide information on workers by zone-of-work down to the census zone level. This data is expected imminently, say, by November or December 2003. This CTPP Part 2 data will then be used to update the zapping proportions for allocating employment below census tract level.

Strategy #1 is to update zonal allocation procedures (zap) to incorporate new Census 2000 journey-to-work data, expected November-December 2003. This strategy would focus on the zapping fractions for allocating ABAG's census tract employment forecasts down to MTC travel analysis zones.

Smart growth may mean that historic patterns of growth *within* census tracts may *not* be the same in the future. That is, the proportion of households and jobs *within* a census tract may need to be adjusted, to account for development shifts. The proposed "Smart Growth Adjustments" will basically examine and adjust these zapping proportions based on growth patterns that may not be evident from historic census data.

An excellent example of this need to review the zapping proportions for "smart growth" is census tract 5050.06 in the eastern "golden triangle" in north San Jose (MTC's travel analysis zones #406, 407, 408, 409, 410). Historically, 98 percent of the households in this census tract are located in our zone 410, and 2 percent of the households are in our zone 408. Zones 407 and 409 are industrial areas that straddle the Santa Clara LRT route along north First Street, and have no historic population data (and their "zapping" proportions for households, population and workers are 0.000!) The "traditional" approach is then to allocate zero future households and population to zones 407 and 409. The "smart growth" approach will be to examine these particular neighborhoods and make a determination whether or not smart growth changes will produce housing units, in a mixed development environment, in these particular neighborhoods.

This strategy is focused *only* on the allocation of activities (households, population, jobs) *within* a census tract. It is not at all intending to examine the re-allocation of activities *between* census tracts.

Strategy #2 is to update the future year zonal allocation procedures in MTC's "split tract" zones to incorporate Smart Growth allocation of jobs and housing. This strategy may affect up to 79 "split tract" zones, but will not change data for the other 1,375 zones.

The last set of strategies in this section focuses on a socio-economic input that is not provided by ABAG: the number of single-family and multi-family households by TAZ or tract. ABAG does provide forecasts, at the census tract level, of the number of households by household income quartile. This is a critically important data input to MTC's travel forecasting process.

The proportion of single-family households of total households (%SFDU) is used in only one MTC model: the "Workers in Household / Vehicles in Household" choice model. This model splits the zone-level households, by income quartile, into nine different choices, stratified first by workers in the households (zero worker, one worker, and multi-worker households), and then by vehicles in the household (zero vehicle, single vehicle, and multi-vehicle households). The "%SFDU" variable is influential in the vehicles in household choice portion of this model. Neighborhoods with high proportions of single-family dwelling units have low numbers of zero-vehicle households and high numbers of multi-vehicle households. Conversely, zones with high proportions of multi-family dwelling units have high numbers of zero-vehicle households and low numbers of multi-vehicle households.

MTC currently uses a "default" model (Model #1) to predict the split of households between single-family and multi-family dwelling units. This "default" model uses historic census data, at the zone level, to split ABAG-provided total households by single family and multi-family. The "default" model is that the zone-level "%SFDU" variable *does not change* between base year 2000 and any horizon year.

An alternative model is to base any change in the year 2000 "%SFDU" variable on the absolute change in net residential density. Net residential density, based on total households divided by residential acres, can be derived from ABAG forecasts. The simple hypothesis of this alternative Model #2 is that the future year single-family / multi-family split is a linear function of the change in net residential density. As residential density increases, the proportion of households within the zone that are multi-family also increases.

Model #2a (percent change capped to a 10% increase) is as follows:

$$CFACTOR_{ik} = \min(1.15,(1+(NRESD_{ik} - NRESD_{i2000}) * 0.03))$$
$$MFDU\_Share_{ik} = \min(0.93, CFACTOR_{ik} * MFDU\_Share_{i2000})$$

Where inputs are:

$NRESD_{ik}$ = Net Residential Density for zone "i" in year "k"
$NRESD_{i2000}$ = Net Residential Density for zone "i" in year 2000
$MFDU\_Share_{i2000}$ = Multi-Family Proportion, zone "i" in year 2000

For example, a zone that increases in net residential from 10 to 12 households per acre would have a 6 percent increase in the proportion of multi-family households. If that zone had 40 percent multi-family of total households in year 2000, the forecast year would show 42.4 percent. The "0.93" factor is a cap on the multi-family share (93% multi-family of total households) and represents the 95th percentile for MTC zones using Census 2000 data.

We will want to test other variations on this model, and then test the sensitivity of the MTC auto ownership forecasts to variations on this multi-family versus single-family split.

The following table highlights some of the single-family / multi-family regional data based on Model #1 and Model #2.

Characteristic	Census 2000	Year 2030, Model #1 (Proj 2003)	Year 2030, Model #2 (Proj 2003)
Multi-Family HH	906,000	1,118,900	1,251,600
Single-Family HH	1,560,000	1,997,700	1,935,000
Total Households	2,466,000	3,186,600	3,186,600
% SFDU	63.3%	62.7%	60.7%
% MFDU	36.7%	37.3%	39.3%

Strategy #3 is to apply improved, density sensitive procedures to predict the proportion of multi-family dwelling units for all travel analysis zones. The difficulty in this density-sensitive %MFDU model is to choose between model #2a, model #2b, etc. Or others in the community may invent a better model that makes better sense than the simple linear model presented here.

The fourth and last short-term strategy in this section is to review, and adjust as appropriate, the single-family / multi-family split in all "smart growth" neighborhoods. To make this an effective strategy we may want to limit our analysis to "smart growth" neighborhoods, then have CMA or other knowledgeable professionals provide guidance on the possible split between single-family and multi-family households for these neighborhoods. Data would be provided that shows the historic, Census 2000 data on multi-family and single-family households; ABAG projected increment of household growth; ABAG projected distribution of households by household income quartile; and ABAG projected change in net residential density.

Strategy #4 is to review and update single-family and multi-family household data in Smart Growth neighborhoods.

Long-term strategies would be to estimate more formal, empirical models that predict the distribution of single-family and multi-family dwelling units. This formal model would be estimated by ABAG or MTC using historical SFDU/MFDU split data and other relationships.

The next section of this report turns to possible adjustments to the highway, transit and non-motorized networks to incorporate Smart Growth improvements.

III. SMART GROWTH ADJUSTMENTS TO TRAVEL MODEL NETWORKS

Three short-term strategies are discussed in this section:

1. Adjust intra-zonal travel times for auto, transit and non-motorized networks to reflect higher density, compact development within Smart Growth neighborhoods.
2. Adjust auto network "terminal times and distances" to reflect higher density, compact development.
3. Adjust transit network walk access connector links to reflect higher density, compact development.

Two significant long-term strategies are also discussed in this section:

1. Produce a geographic market segmentation of zones to represent portions of zones with very short walks (< 0.25 miles), moderate walks (0.25 to 0.50 miles), long walks (0.50 to 1.00 miles) and not walkable (> 1.00 miles) to transit.
2. Create distinct and different networks and intra-zonal travel time calculations for walk and bicycle travel modes.

One of the basic assumptions in traditional travel demand forecasting is that the distribution of jobs and housing units *within* a travel analysis zone does not change year-by-year. For example, if 50 percent of a zone's population is within a half-mile walk of transit in the base year, then 50 percent of that zone's population is within a half-mile walk of transit next year, the following year, and thirty years in the future.

Smart Growth, on the other hand, is predicated on a more compact, dense, mixed land uses, which means that the future year distribution of within-zone activities is typically different ("smarter") than the base year distribution of within-zone activities. In the previous example, 50 percent of the zone's population may be within a half-mile of transit in the base year, but due to smart growth densification, 70 percent of the zone's population may be within a half-mile of transit by the long-range horizon year.

A solution is to adjust the intra-zonal times and distances for auto, transit and non-motorized networks to represent the compactness of Smart Growth neighborhoods, and to adjust the "terminal" times for these modes to represent the shorter accessibility from a typical household or job to the greater regional network. An article by Walter, Ewing and Schroeer (1) discusses intra-zonal travel time adjustments for Smart Growth representation.

The current set of MTC travel demand models do not, however, have the geographic market segmentation that would allow us to adjust the proportion of a zone's population which are within "x" minutes of a transit stop. This "geographic segmentation" process is a long-term strategy that can now take full advantage of MTC's GIS (geographic information systems) technologies. (For more information on this subject, re-visit the class notes for the NTI course on Multimodal Travel Forecasting). The short-term strategy is to adjust the intra-zonal and terminal times to account for the smart growth re-distribution of activities (households, jobs) within zones.

The process will be to first identify the Smart Growth neighborhoods, and the Transit-Oriented Development neighborhoods where modest adjustments to these network parameters can be tested.

The second step will be to test sets of travel time reductions for these smart growth zones. This is an extremely subjective and heuristic (trial-and-error) process, so we may want to test intra-zonal reductions ranging from 10 to 25 percent. This will be a fairly manual but simple process, focusing on updating the "intra-zonal" override values that are currently in our network analysis processes.

Special attention should be paid to the intra-zonal values for non-motorized trips. The current set of non-motorized zone-to-zone travel times works very well for bicycle travel, and less well for walk-only travel. Intra-zonal travel times for walk trips are typically much shorter than the intra-zonal travel times for bicycles, but our current set of intra-zonal times are more appropriate for bicycles. It is clear that we need to conduct a zone-by-zone review of non-motorized travel times in the context of our year 2000 model validation efforts. Ideally we would re-write all of our mode choice model software to split the non-motorized network levels-of-service file to have zone-to-zone bicycle travel times distinct from our zone-to-zone walk times. This would be extremely time-consuming and difficult given the recent retirement of MTC computer programming staff. In the long term (post-2004), we should probably specify independent sets of network data for bicycle versus walk-only travel.

It is fairly evident that smart growth patterns will decrease intra-zonal travel times for all modes, including auto, transit and non-motorized modes, and not just transit and non-motorized. It will also be desirable to test the impact of these reduced intra-zonal travel times on work and non-work trip distribution (trip destination) forecasts. The overall impact should be shortened regional trip lengths, which in turn will yield slightly higher non-motorized modal shares.

<u>Strategy #1 is then to adjust intra-zonal travel times for auto, transit and non-motorized networks to reflect higher density, compact development within Smart Growth neighborhoods.</u>

The second strategy is to reduce the “terminal times and distances” for auto modes. These data are currently kept the same between base year and future year. This is the “auto zonal level of service” file, or “AZLOS” file. Changes should be fairly modest at perhaps a 10 to 20 percent reduction in value. Variables that should be modified include:

- Time to walk from parking lot to activity
- Time to get from typical location (household, job) to the regional network
- Distance to get from typical location (household, job) to the regional network

Another strategy that could be investigated or tested at this juncture is the use of auto parking charges in smart growth zones. This “auto zonal level of service” file contains not only the terminal times and distances but also the peak and off-peak parking costs. Perhaps a modest charge of $1.00 per day for Smart Growth zones in non-downtown areas may be appropriate. We should keep this in mind when reviewing the full set of pricing assumptions for the regional transportation plan update.

<u>Strategy #2 is then to adjust auto network “terminal times and distances” to reflect higher density, compact development.</u>

The third network management strategy is to adjust the transit network terminal times, that is, the walk access connectors that link the “centroids” of the travel analysis zones with the regional transit network.

MTC uses the computer software TP+ to prepare highway, transit and non-motorized networks. The "walk-access-to-transit" process is a computer-automated process controlled by user-defined parameters such as maximum walk distances to transit by mode (transit sub-operator) of travel.

The proposed transit network adjustment process will first, identify the Smart Growth zones and transit-oriented development (TOD) zones in the Bay Area. The next step will be to manually flag the walk-access-to-transit links and adjust their distances downward, say, by 10 to 25 percent. For example, a suburban Smart Growth zone that is automatically coded at a 0.50-mile average walk distance can be adjusted to 0.40-mile average walk distance, a savings of 2.0 minutes of walk travel time. We have already developed a TP+ program that can be used to adjust these walk connector distances, so the more important and immediate activity is to identify the Smart Growth and TOD zones.

<u>Strategy #3 is then to adjust transit network walk access connector links to reflect higher density, compact development.</u>

The long-term strategy is to replace this "adjust walk access to transit network" strategy with the "geographic market segmentation" strategy. MTC will use our GIS system to break-out the proportion of our travel analysis zones that are (for example) within 0.25 miles of transit stops, within 0.25 to 0.50 miles of transit, within 0.50 and 1.00 miles of transit, and greater than 1.00 mile walk to transit. We will use our GIS base maps in conjunction with the transit stop data being assembled for use by our transit trip planner project. Data from Census 2000 will be used to get precise estimates of population and jobs within each of these walk markets. These data (e.g., proportion of population within 0.25 miles of transit stops) can then be selectively updated, in future year forecasts, to represent the re-allocation of development within a travel analysis zone due to Smart Growth strategies.

Another critical data component for the long-term market segmentation strategy is the detailed trip data from the year 2000 Bay Area Travel Survey (BATS2000). Household locations and trip end data from BATS2000 is being geo-coded to very precise origins and destinations. We will use these precise locations in conjunction with our master transit stop GIS data layer to calculate a precise distance between all locations to the nearest transit stop. This will be a key strategy in travel model estimation so that we should have a precise and accurate estimate of each person's accessibility to transit, as opposed to using a zonal average walk time to transit.

Another BATS2000 strategy that will be extremely beneficial to future sets of demand models is that we intend to use the precise origins and destinations to create a "best walk path" and "best bicycle path" between all sample trips in the data file. This will essentially be a "disaggregate" trip-level point-to-point travel distance and time, instead of the traditional "aggregate" zone-to-zone travel distance and time.

This concludes this report in terms of short-term strategies to incorporate the effects of Smart Growth and TOD in Bay Area travel demand models. Some very specific long-term strategies are also discussed in this report, but a comprehensive model design strategy to update any new set of MTC travel behavior models to incorporate BATS2000 and other data will be defined in future studies.

The following box is a summary of the short-term strategies:

SHORT-TERM STRATEGIES: MTC TRAVEL MODEL ADJUSTMENTS

SMART GROWTH ADJUSTMENTS TO MASTER ZONAL DATABASES

5. Update zonal allocation procedures ("zap") to incorporate new Census 2000 journey-to-work data, expected November-December 2003.
6. Update the future year zonal allocation procedures in MTC's "split tract" zones to incorporate Smart Growth allocation of jobs and housing.
7. Apply improved procedures to predict the proportion of multi-family dwelling units for all travel analysis zones.
8. Review and update single-family and multi-family household data in Smart Growth neighborhoods.

SMART GROWTH ADJUSTMENTS TO TRAVEL MODEL NETWORKS

4. Adjust intra-zonal travel times for auto, transit and non-motorized networks to reflect higher density, compact development within Smart Growth neighborhoods.
5. Adjust auto network "terminal times and distances" to reflect higher density, compact development.
6. Adjust transit network walk access connector links to reflect higher density, compact development.

This report concludes with a list of annotated references, and Appendix "A": "Variables Used to Predict Bicycle and Walk Trips in MTC Mode Choice Models" This appendix provides data on the model coefficients and their statistical strength (t-statistic) for the bicycle and walk equations used in all of MTC's current model choice models. The overall theme of this table is that travel time (distance) is a critical variable in choosing whether or not to travel by bicycle or walk. There are other supporting variables that have been tested and contribute, including employment density variables, household size, income, vehicle ownership, and "dummy" (or "Boolean" 1 or 0) variables to represent bicycling proclivities in Stanford, Palo Alto and Berkeley.

In future MTC model systems we would like to test other variables that may be significant for incorporating in bicycle and walk choices, such as route level (point-to-point) gross elevation changes, and network connectivity (e.g., average block size.) The most critical component of future, improved modeling for bicycle and walk modes is the use of disaggregate, “door-to-door” distance data appended to trip records in the 2000 Bay Area Travel Survey.

IV. ANNOTATED REFERENCES

1. Gerard Walters, Reid Ewing and William Schroeer "Adjusting Computer Modeling Tools to Capture Effects of Smart Growth" in *Transportation Research Record* 1722 TRB, National Research Council, Washington, D.C., 1990, pp. 23-32.

- EPA-commissioned study of a proposed Atlanta development, comparing "greenfield" sites with a redevelopment of the Atlantic Steel ("brownfield") site.
- The purpose of this study was to reduce the predicted automobile traffic at the Atlantic Steel site to account for the Smart Growth nature of the site, and the site design.
- Study includes borrowing a lot of information from west coast areas, including San Francisco and Portland. This is hardly an ideal process, more like a patchwork process, and has a real potential for underestimating the automobile traffic due to unreasonably optimistic assumptions. (See Crane's discussion on hypothetical studies.)
- Best information from this paper is topics on "zone structure and related trip length profiles" and "representation of transit accessibility."

2. Thomas F. Rossi. "Modeling Non-Motorized Travel" Paper presented at the 79th Annual Meeting of the Transportation Research Board, Washington, D.C., 2000.

- Compares non-motorized modeling activities in Boston for the Central Artery study; Portland (LUTRAQ), and the Philadelphia regional model system.
- These models are intended to "patch" the existing models to account for non-motorized travel, as opposed to fully integrating non-motorized modes into all models.
- Good idea in the Boston study to identify three major components of walk travel: walk-only travel; walk access and egress from transit; and walk access and egress from autos (e.g., time to walk from parking lot to office front door.)
- Review of Portland LUTRAQ model to apply a "pre-mode choice" model with a combined non-motorized choice (bicycle+walk) but not separate bicycle and walk choices. Use of a "pedestrian environment factor" as a linear combination of four variables: sidewalk availability; ease of street crossing; street connectivity; and terrain. (See Krizek in other studies to examine non-linear combinations of land use / neighborhood accessibility variables, as an alternative to the linear combination). No statistics provided as to the strength of the PEF factor.
- Philadelphia model system was retrofitted to include a motorized / non-motorized mode choice split, after trip generation but before trip distribution. The PEF factor used in the Philadelphia system used a weighting approach for sidewalk availability, ease of street crossing and building setbacks. The t-statistic on the Philadelphia PEF factor was 1.7, which is modest, but is not "statistically significant" as the author claims. Average trip distance is not used in the Philadelphia pre-mode choice model, unlike the Portland LUTRAQ.
- My concern is that pedestrian environment factors (PEF) as expressed in these studies are zone-based attributes, as opposed to route-based attributes. The linear combination of these zone-based attributes to concoct an overall index doesn't make much intuitive sense, but some of the research by Krizek may be useful in devising a superior alternative. In addition, our proposed work on analyzing point-to-point distances and elevation changes will be a major benefit to our future work.
- A problem with these "pre-mode choice" models is that improvements or deterioration in highway or transit travel times and costs have no impact on the share of trips that are non-motorized. For example, transit improvement projects will decrease transit travel times, increase transit trips and decrease auto trips; but in a pre-mode choice model

increased investments in autos or transit will have precisely zero impact on non-motorized choices. This is overly simplistic.

3. Michael Pawlukiewicz. "What is Smart Growth?" <u>in</u> *Urban Land*, June 1998, pp. 45-48.

- "It must be understood that smart growth is local. Built up from the grassroots level, smart growth rejects top-down, command-and-control policy implementation. The first defining principle for smart growth should be the understanding that growth and development are necessary and can enhance a community's vitality, economic well-being, and environmental quality."
- "How can smart growth be recognized? It can be said that smart growth is happening in a community when:
  - o Development is economically viable and preserves open space, natural resources, and sustainable habitats;
  - o There is certainty and predictability in the development process, and development projects that enhance the economy, the community, and the environment get expedited approval;
  - o Existing infrastructure is maintained and enhanced but expanded when appropriate to serve existing and new residents;
  - o There is mutually beneficial collaboration among the community, the nonprofit sector, and the public and private sectors;
  - o Redevelopment is actively pursued, including infill residential development, the reuse of brownfields, and the recycling of obsolete buildings;
  - o Compact development is focused on existing commercial centers, new town centers, and existing or planned transportation facilities;
  - o Land planning and urban design create a sense of community and ensure the ease of movement and safety of residents'
  - o Traditional downtowns and urban neighborhoods are recognized as being important to the economic health of the region."
- Pawlukiewicz is the Urban Land Institute's Director of Environmental Land Use Policy.

4. Edward McCormack, G. Scott Rutherford and Martina G. Wilkinson. "Travel Impacts of Mixed Land Use Neighborhoods in Seattle, Washington" <u>in</u> *Transportation Research Record* 1780 TRB, Washington, D.C., 2001, pp. 25-32.

- Research based on travel diaries collected in three mixed-use neighborhoods (Queen Anne, Wallingford, Kirkland) compared to regional diary data.
- "Residents of the two mixed land use neighborhoods in Seattle traveled 28 percent fewer kilometers (miles) than the residents in the remainder of North Seattle….The trend of traveling fewer kilometers per day held across different socioeconomic characteristics."
- "The large differences in travel distance among the areas are not seen when travel time is considered. The travel time was about 90 min per person, regardless of where that person lived. The variation by age and family life cycle stage was also remarkably small. This 'travel time budget' of about 90 min is an interesting finding and compares favorably to data from previous studies."
- "This slower travel speed in mixed land use neighborhoods combined with a travel time budget has an interesting implication for the neotraditional neighborhood movement. If a mixed land use does make shopping and other chores more convenient and quicker, this may simply leave more time to be used for additional travel. Crane recognized this when he noted that the improved access associated with a mixed land use neighborhood would reduce the cost of travel and could lead to travel by automobile becoming more attractive

[Crane, JAPA, 1996]. He noted that this could results in the benefits of mixed land use neighborhoods being greatly overstated."

- Fascinating results gives us more reason to re-investigate travel time expenditures using BATS2000.

5. Kevin J. Krizek. "Operationalizing Neighborhood Accessibility for Land Use-Travel Behavior Research and Regional Modeling" <u>in</u> *Journal of Planning Education and Research* 22, 2003, pp. 270-287.

- Excellent article on strengths and weaknesses for developing neighborhood accessibility (NA) indices for travel behavior and modeling. Krizek has some good, practical advice that can help MPOs.
- Taxonomy and classification for urban form impacts on travel behavior, reflecting "three Ds" relating to density, diversity and design.
- Developed a raster-based (150-meter grid cell) estimate of neighborhood accessibility for the Seattle region using census and disaggregate employment record data. This may be a very useful role for the ArcGIS Spatial Analyst software here at MTC.
- "The majority of past research, however, depicts the neighborhood unit by aggregating information to census tracts, zip codes, or TAZs. These units often do little justice to the central aim; they can be quite large, almost two miles wide containing more than one thousand households. *The problem is that an ecological fallacy arises because average demographic or urban form characteristics are assumed to apply to any given neighborhood resident*." [Emphasis added] What this means to me is that we will be much better off calculating disaggregate levels of neighborhood accessibility (how close is MY house to the nearest grocery store) than calculating aggregate levels of NA (how close in my NEIGHBORHOOD to the nearest grocery store.)
- See also Krizek's article in the summer 2003 Journal of the American Planning Association: "Residential Relocation and Changes in Urban Travel: Does Neighborhood-Scale Urban Form Matter?" for a different spin on his Seattle research.

6. Randall Crane. "The Influence of Urban Form on Travel: An Interpretative Review" <u>in</u> *Journal of Planning Literature* 15:1, August 2000, pp. 3-23.

- Comprehensive and critical literature review of scholarly studies on urban form and travel. Crane reviews "hypothetical studies" (e.g., Calthorpe, LUTRAQ); "descriptive studies"(e.g., Rutherford); "ad hoc models" (e.g., Handy, Cervero, Holtzclaw); and "demand models" (e.g., Kain, Giuliano, Shen, Boarnet). Very important resource.
- "How should policy makers be advised to the use of urban design and land use tools to reduce traffic in new or retrofitted neighborhoods? It is difficult to say. Although some relationships between land use and travel appear straightforward, such as that between density and trip length, these simple observed correlations are not so simple upon closer examination. Rather, they represent the complex interactions of many factors. Land / travel linkages are both multidimensional and difficult to deconstruct, and little if any hard evidence indicates how the built environmental can reliably manipulate travel behavior. The best advice might be to keep expectations low until more is known. The risks of doing otherwise go beyond disappointment, and include unintended consequences such as worsening traffic problems."
- "Demand studies on the influence of urban form on travel have more appeal than other standard approaches, given their attention to such basic issues as travel costs and behavioral trade-offs." I strongly agree with Crane, though I believe we should start from a set of comprehensive "descriptive studies" based on our 2000 travel survey, and we may also need to produce some simple "ad hoc" models that could be used in such sketch

planning / GIS models as INDEX, PLACE^{3}S and other "planning support system" software. We should probably avoid the problems of "hypothetical studies" such as that described in the Walters/Ewing/Schroeer paper.

7. Robert Cervero and Kara Kockelman. "Travel Demand and the 3Ds: Density, Diversity, and Design" in *Transportation Research D* 2:3, 1997, pp. 199-219.

- Ad hoc models of different travel characteristics, including VMT per household and simple binomial logit mode choice models. There are some good ideas in this paper for improving "sketch planning" models such as INDEX and PLACE^{3}S, and perhaps some useful ideas for more comprehensive demand models.
- Data for these models is from the 1990 MTC household travel survey. Authors used data from 50 census tracts, with data from 936 total sample households. Full survey was 9,359 households, so authors only used 10 percent of available data. They probably did this because assembling the density, diversity and design variables for all census tracts would have been too time-consuming. The authors complain about the "problem encountered in attempting to model mode choice for walk trips alone, however, was the shortage of cases." This is a red herring issue, since the authors avoided using 90 percent of BATS data. My concern is that the authors seem to believe that the appropriate unit of observation is the neighborhood (census tract) and not the household.

8. Kevin J. Krizek. "Neighborhood Services, Trip Purpose, and Tour-Based Travel" in *Transportation* 30: 2003, pp. 387-410.

- Continuation of Krizek's research using Puget Sound Transportation Panel survey data, this time focusing on the relationships between neighborhood accessibility (NA) and chained, or tour-based trips. Very good discussion of tour-based travel typologies. Very good ideas that can be tested in future MTC research.
- Very recent research, and apparently one of the first examples of research that examines urban form and trip chaining.
- "Crudely simplified, the findings suggest that households in higher levels of NA tend to leave home more often, but they tend to make fewer stops when they do….While higher NA households travel shorter distances for maintenance-type errands (personal, appointment, and shopping), the findings suggest that a large portion of their maintenance travel is still pursued outside the neighborhood; a mere 20 percent of their simple maintenance tours are within 3.2 km (2.0 mi) of their home (in contrast to a mere 1.7 percent for households in the lower half of neighborhood accessibility)."

(This annotated reference list is a "work in progress." There are scads of other research articles, books, manuscripts and information that will need to be scanned in the years ahead to mine for ideas. It's better to stop now and get to work on integrating these improvements for the short-term.)

APPENDIX TABLE A
Variables Used to Predict Bicycle and Walk Trips in MTC Mode Choice Models

A.1 Bicycle Choice: Work Trip Mode Choice Model

Variable	Coefficient	T-Statistic
Bicycle Travel Time	-0.03326	(4.3)
Natural Log of Employment Density in zone-of-residence	+0.3243	(2.2)
Stanford, zone-of-work	+2.09	(3.0)
Palo Alto, zone-of-work	+1.584	(2.3)
Berkeley, zone-of-work	+1.01	(1.5)

A.2 Walk Choice: Work Trip Mode Choice Model

Variable	Coefficient	T-Statistic
Natural Log of Walk Travel Time	-2.137	(13.5)
Natural Log of Employment Density in zone-of-work	+0.1418	(2.1)

A.3 Bicycle Choice: Home-Based Shop/Other Mode Choice Model

Variable	Coefficient	T-Statistic
Bicycle Travel Time	-0.05815	(13.5)
Stanford, zone-of-shop	+2.488	(2.5)
Palo Alto, zone-of-shop	+1.377	(1.7)
Berkeley, zone-of-shop	+1.630	(3.0)

A.4 Walk Choice: Home-Based Shop/Other Mode Choice Model

Variable	Coefficient	T-Statistic
Walk Travel Time	-0.05815	(13.5)
Zero-Vehicle Household	+1.7350	(6.6)

A.5 Bicycle Choice: Home-Based Social/Recreation Mode Choice Model

Variable	Coefficient	T-Statistic
Bicycle Travel Time	-0.02745	(3.4)
Stanford, zone-of-play	+2.2090	(2.9)
Household Income	-8.8820E-03	(1.7)

A.6 Walk Choice: Home-Based Social/Recreation Mode Choice Model

Variable	Coefficient	T-Statistic
Walk Travel Time	-0.06806	(11.9)

A.7 Bicycle Choice: Non-Home-Based Mode Choice Model

Variable	Coefficient	T-Statistic
Bicycle Travel Time	-0.03232	(4.6)

APPENDIX TABLE A (continued)
Variables Used to Predict Bicycle and Walk Trips in MTC Mode Choice Models

A.8 Walk Choice: Non-Home-Based Mode Choice Model

Variable	Coefficient	T-Statistic
Walk Travel Time	-0.07583	(19.5)
Area Density, Zone-of-Origin	+4.173E-04	(1.8)

A.9 Bicycle Choice: Home-Based Grade School Mode Choice Model

Variable	Coefficient	T-Statistic
Bicycle Travel Time	-0.05855	(4.1)

A.10 Walk Choice: Home-Based Grade School Mode Choice Model

Variable	Coefficient	T-Statistic
Walk Travel Time	-0.06384	(10.7)
Household Size	+0.004436	(5.4)

A.11 Bicycle Choice: Home-Based High School Mode Choice Model

Variable	Coefficient	T-Statistic
Bicycle Travel Time	-0.03228	(1.7)

A.12 Walk Choice: Home-Based High School Mode Choice Model

Variable	Coefficient	T-Statistic
Walk Travel Time	-0.03463	(5.9)

A.13 Bicycle Choice: Home-Based College Mode Choice Model

Variable	Coefficient	T-Statistic
Bicycle Travel Time	-0.07129	(2.6)
Stanford, Zone-of-Residence	+3.216	(3.1)
Palo Alto, Zone-of-Residence	+2.668	(2.8)
Berkeley, Zone-of-Residence	+1.711	(2.5)

A.14 Walk Choice: Home-Based College Mode Choice Model

Variable	Coefficient	T-Statistic
Walk Travel Time	-0.09188	(6.2)

APPENDIX B
OTHER IDEAS TO KEEP IN MIND

1. Route-Based Gross Elevation Change. One of our ideas is to use the BATS2000 trip data to develop origin-destination polylines. This would then give us our best estimate of trip distances for walk, bicycle, transit and auto trips. These "door-to-door" distances should prove much more useful for mode choice estimations, especially for bicycle and walk trips (chosen versus available modes.) Another idea is to compute the gross elevation change between trip origins and trip destinations. Our summer 2003 GIS intern, Xing Liu, developed a means to do this using ESRI Spatial Analyst by first, converting the polyline into raster cells, then using raster-based calculations to analyze elevation gain and loss going from raster cell to raster cell, then summing up the total changes across the rasterized polyline to yield a gross elevation change. Our challenge is to somehow automate this process for over 200,000 disaggregate trip records. Again, the hypothesis is that the greater the distance and the greater the elevation changes, the less likely the traveler will choose bicycle or walk modes.

2. Use of Average Block Size as a Neighborhood Design Variable. An alternate approach is to tally the number of intersections within, say, one mile of the sample household. I recently reviewed some Census 2000 data at the block group level to understand this relationship between average block size and journey-to-work characteristics. This is similar to my work on census characteristics by gross density, but focuses instead on average block size. For the 4,422 block groups in the Bay Area, the average block size is 28.25 acres per block. This ranges from 1.15 acres per block to 2,548.59 acres per block. The median acres/block in the Bay Area is 8.26 acres per block. I designed a simple tally of means of transportation to work by six average block size categories. Results are summarized in the following table:

Average Acres per Block	Character	# of Block Groups	% Transit	% Bicycle	% Walk	% At Home	% Drive Alone	% Carpool
< 3.5	Urban	384	24.1%	2.0%	10.2%	3.8%	45.7%	12.6%
3.5 – 5.0	Urban	749	21.1%	2.0%	5.7%	4.2%	52.6%	12.9%
5.0 – 8.0	Suburb	1,005	8.6%	1.1%	2.9%	3.4%	69.2%	13.7%
8.0 – 15.0	Suburb	1,172	5.8%	0.7%	1.7%	3.4%	74.6%	12.9%
15.0 – 50.0	Rural	713	5.7%	0.9%	1.9%	4.4%	73.7%	12.5%
> 50.0	Rural	399	4.4%	0.4%	2.3%	6.3%	73.2%	12.4%
Total		4,422	9.7%	1.1%	3.2%	4.0%	68.0%	12.9%

A map might help. Clearly, dense highway networks have the highest transit, bicycle and walk shares for residential neighborhoods. The work at home share is significantly higher in rural communities. Carpooling appears to be indifferent to this particular variable.

Ideally, we will calculate the average block size for each household in BATS2000, say, based on the number of blocks within a one-mile radius. This will be the best available, "disaggregate" measure of urban design that can be produced with available data. In terms of "aggregate" model application we would use the average block size for the travel analysis zone. The challenge will be to predict the change in average block size, by TAZ, for future year forecasts.

3. Measuring Proximity of BATS2000 Households to Nearest Land Uses. One particularly interesting database is ABAG's land use GIS database. See the ABAG report "Existing Land Use in 2000: Data for Bay Area Counties." MTC staff has used this data, in conjunction with ABAG's

census tract-level employment data, to allocate employment-by-employment sector to ABAG's land use polygon files. (See Purvis' SAS scripts produced April 2003.) We want to do this so we can get a handle on micro-scale employment accessibility to different transit stops and stations. The ABAG land use data uses the USGS Anderson coding scheme, and is not as detailed as some of the scholarly papers that I've reviewed. Still, this could be very useful in developing a retail and services accessibility variable for our BATS2000 analysis. This would essentially use the ESRI Network Analyst software to determine the distance to the closest polygon for land use category "x" "y" and "z" as well as the attributes of the closest polygon, say, the total acreage and the allocated employment values. Or, we could rasterize the ABAG land use polygons into 150-meter grid cells, following on some of the research by Krivek, and Cervero-Kockelman.

Another idea is to purchase disaggregate (firm level, address-level) employment data from Dun and Bradstreet or other data vendors. This may be an expensive solution, but the Dun and Bradstreet data may be useful for other MTC activities such as the online transit trip planner, so costs could be shared across MTC programs.